37th CONFERENCE OF
DIRECTORS GENERAL OF CIVIL AVIATION
ASIA AND PACIFIC REGIONS

WELLINGTON, NEW ZEALAND
November 13-17, 2000

RECENT DEVELOPMENTS IN THE MODERNIZATION OF THE GLOBAL POSITIONING SYSTEM (GPS)

AND

U.S. SATELLITE NAVIGATION PROGRAM STATUS

INFORMATION PAPER

(Presented by the United States)

SUMMARY

This information paper provides an update on the Global Positioning System (GPS) modernization efforts of the United States, highlighting the recent decision by the President to discontinue the intentional degradation of the civilian GPS signal, a feature known as Selective Availability (SA). This decision, which occurred at midnight GMT on May 1, 2000 has resulted in a significant increase in the three dimensional position (longitude, latitude, altitude) information provided to the international civil aviation community and other peaceful civil users of GPS. Additional information is included on the status of the Federal Aviation Administration's (FAA) GPS augmentation programs, better known as the Wide Area Augmentation System (WAAS) and the Local Area Augmentation System (LAAS).

1. The Future of Navigation

1.1 As the 20th Century ends and we embrace the 21st Century, the groundwork we are now laying through the development and implementation of revolutionary new technologies, will be the backbone of the Air Traffic Management (ATM) system for the next one hundred years. Satellite navigation technology is already blossoming and represents probably the single most important technological breakthrough in civil aviation navigation since radar was introduced over fifty (50) years ago.

1.2 Satellite navigation technology is already in use in the United States and elsewhere as a navigation aid for enroute, oceanic and remote airspace, and also for non-precision approaches. The U.S. Global Positioning System (GPS) provides this service as an integral part of the International Civil Aviation Organization's (ICAO) envisioned Global Navigation Satellite System (GNSS).

1.3 Satellite navigation, represented by GPS and its various augmentation systems under development today, provides significant flight safety and system capacity benefits by making precision approaches possible at thousands of airports worldwide where no such capability exists today. As this technology is based on positioning information provided from space, implementation is not dependent or restricted due to the availability of ground-based navigation infrastructures. As such, the benefits of satellite navigation will be especially significant in many developing countries where the ground-based navigation aids needed to support safe civil aviation operations are limited or even non-existent.

1.4 Additionally, satellite navigation will bring about crucial capacity enhancements that will help meet the growing worldwide demand for air transport services well into the next century. Service providers benefit from lower costs of procuring new navigation equipment, as well as from lower life cycle costs. Commercial air carriers gain from their ability to fly more efficient routes, saving time and money on each and every flight.

1.5 However, these economic advantages don't measure up to the single, most important benefit of satellite navigation - SAFETY! The use of basic GPS in en route, oceanic, and remote airspace, as well as for non-precision approaches, has already improved flight safety in U.S. airspace. The introduction of new, straight-in approach procedures has reduced the need for procedure turns and circling approaches. GPS provides a very reliable and accurate navigation system that dramatically improves safety over a Non-directional Beacon (NDB) approach or a VHF Omni-directional Range (VOR) approach when the VOR is not collocated with the runway. GPS has also improved safety for en route navigation, providing a navigation service at low altitudes where no navigation service previously existed due to line-of-sight limitations associated with ground-based navigation aids. Oceanic operations have also been made safer by replacing Omega navigation, a rather inaccurate and unreliable system, with GPS.

2. GPS Modernization

2.1 As a direct result of these benefits to the civil community, the United States announced a significant modernization effort in January 1999 to extend the capabilities of GPS beyond those currently provided by today's GPS constellation.

2.2 One of the main components of this modernization effort is the addition of two new civil navigation signals. These signals will be in addition to the existing civilian service broadcast at 1575.42 MHz (L1). The first of these new signals will be a Coarse/Acquisition (C/A) code located at 1227.60 MHz (L2) that will be added to the remaining 12 Block IIR satellites and be available for general use in non safety-critical applications. This capability will also be added to all future Block IIF satellites. Current timelines have the first scheduled launch of a Block IIR satellite with L2 occurring in 2003.

2.3 The Block IIF satellites will not only broadcast L1 and L2 signals, but will also broadcast an additional civil signal located at 1176.45 MHz called L5 to support civil safety of life operations. The first scheduled launch of the enhanced Block IIF satellites with L5 onboard is currently scheduled for 2005. This new L5 signal falls in a band which is protected worldwide for aeronautical radionavigation, and therefore will be protected for safety-of-life aviation applications. L5 will provide significant benefits above and beyond the capabilities of the current GPS constellation, even after the planned second civil frequency (L2) becomes available. Benefits include more precise navigation worldwide, increased availability of precision navigation operations in certain areas of the world, and interference mitigation.

2.4 At the current GPS satellite replenishment rate, all three civil signals (L1-C/A, L2-C/A, and L5) will be available for initial operational capability by approximately 2010, and for full operational capability by approximately 2013.

3. Selective Availability (SA)

3.1 Selective Availability (SA), implemented March 25, 1990 on all GPS Block II satellites, is a technique to reduce the accuracy of unaugmented, single-receiver GPS measurements. This is accomplished by altering (or "dithering") the GPS satellite clock signals, and by modifying orbital elements of the broadcast navigation message. These alterations are done in a coded fashion, and could be removed by authorized users. This alteration causes horizontal and vertical positional errors on the order of 100 meters and 140 meters, respectively (95% of the time). Basically speaking, SA is the intentional degradation of the civilian GPS signal.

4. Discontinuation of Selective Availability

4.1 The 1996 Presidential Decision Directive relating to established U.S. Global Positioning System Policy, stated the intention to discontinue SA by 2006. This directive mandated yearly reports to the President, beginning in 2000, regarding the continued use of, and need for SA. To support this determination, the Secretary of Defense, in cooperation with the Secretaries of State, Transportation, and Commerce, and the Director of Central Intelligence along with the heads of other appropriate departments and agencies, provided an assessment and recommendation on continued SA use.

4.2 The first report was submitted as scheduled in early 2000, and after careful examination, the President of the United States decided to discontinue SA at midnight Greenwich Mean Time (GMT) on May 1, 2000. This decision provided the highest unaugmented accuracy possible with the existing GPS constellation to all civil users of GPS worldwide.

4.3 Discontinuing the use of SA improves the accuracy of GPS for civilian users from hundreds of feet to tens of feet (see Attachments for additional information and comparisons of GPS performance with SA on and off). The increased performance of GPS, which is broadcast free of charge to the entire world, is expected to accelerate its acceptance and use by businesses, governments, and private individuals around the globe.

4.4 Basic GPS is already being widely used throughout the world to overcome many of the deficiencies in today's air traffic infrastructure. With its accurate, continuous, all-weather, four (3D position plus time) dimensional guidance, GPS offers an initial navigation service that will satisfy many of the requirements of aviation users worldwide. The discontinuance of SA will only make the performance of this free worldwide GPS service even more accurate, thus allowing for expanded civil use.

4.5 It is important to note that the discontinuation of SA will not eliminate the need for differential GPS systems such as the U.S. Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS). Augmentations to GPS are still necessary to provide increased accuracy to meet the strict requirements for precision approach operations. Current GPS performance without SA still exceeds FAA and ICAO standards for precision approach operations. Additionally, WAAS and LAAS will enhance system availability, and more importantly system integrity and continuity of service that the GPS constellation in its current state cannot guarantee for safety-of-life operations.

5. Wide Area Augmentation System (WAAS)

5.1 In its initial phase of implementation, WAAS will use a network of ground reference stations (WRSs) and two existing INMARSAT III geostationary communication satellites (GEOs) to establish certifiable service in the oceanic, en route, non-precision, and even precision approach domains. The entire Phase I complement of 25 reference stations, two master stations, four geostationary communication satellite uplink facilities, two INMARSAT III GEOs, and an expansive, diverse terrestrial communications network linking all of these system components has already been fully installed, and is currently going through comprehensive operational and safety tests.

5.2 The manner is which WAAS operates is relatively simple. Signals from GPS satellites are received by the WAAS ground reference stations, which are located at precisely surveyed locations. Since each reference station is precisely surveyed, and thus knows exactly where it is located (longitude/latitude/altitude), it is able to determine any errors in the GPS navigation signals being observed throughout the geographic region. Each reference station then relays through either terrestrial ground links or satellite communications links this region-specific data to a WAAS master station (WMS), where the GPS signal correction information for the entire WAAS coverage area is computed. A corresponding WAAS correction message is then prepared by the master station and uplinked to one of the two initial INMARSAT III geostationary communications satellites via a ground uplink station (GUS). The message is then broadcast on the same frequency as GPS (L1, 1575.42 MHz) to GPS/WAAS receivers on board aircraft (or other modes of transportation) that are located within the WAAS broadcast area.

5.3 WAAS Phase I Stability Testing commenced in December 1999 and demonstrated total system accuracy to be much better than originally anticipated or required. The accuracy requirement for WAAS Phase I is 7.6 meters (horizontal and vertical) and preliminary test results show that total system accuracy is approximately 2-3 meters (horizontal and vertical).

5.4 However, these tests also identified several corrections/modifications that need to be completed in the areas of system stability and integrity. The FAA successfully conducted a 21-day Stability Retest in June 2000 and immediately announced that the WAAS Signal in Space will be continuously available for aviation users to increase situational awareness during VFR flight, as well as for non-aviation users for recreational, maritime, agricultural, surveying, and other applications requiring precise positioning and time. As a result of these unscheduled corrections and additional work, the originally scheduled operational approval for Phase I WAAS in CY2000 was not attainable. Current schedules project that the initial operating capability for Phase I WAAS will now be in CY2002.

6. Local Area Augmentation System (LAAS)

6.1 The Local Area Augmentation System (LAAS) is the second augmentation to the GPS signal that will complement the WAAS in U.S. airspace to provide full satellite-based precision approach and landing capability for all phases of flight down to Category IIIb auto-landings. In practical terms, this means that LAAS will meet the more stringent Category IIIa and IIIb precision approach requirements that exist at select locations throughout the U.S. today, as well as provide a Category I precision approach capability at locations where availability requirements are greater than 99.9% or geographic limitations inhibit consistent GPS signal reception. For example, LAAS will provide Category I service to airports with extremely high availability requirements (e.g., Chicago O'Hare International Airport).

6.2 The LAAS ground station, as it is being developed, will be able to support Category I, II, IIIa, and IIIb operations depending on the airport-specific service requirements. This will be accomplished through a modular deployment of supporting equipment that is designed to increase levels of availability to ensure continuity of operations critical for Category II and III operations. These different configurations result out of the need for increased frequency of satellite range measurements and redundancy necessary for locations with higher availability requirements. The LAAS architecture may also consist of Airport Pseudolites (APL) that act and function just like

GPS satellites, but will be located on the ground to enhance the availability of LAAS service by providing an additional ranging source that originates from the local airport.

6.3 The final LAAS architecture is currently being addressed in conjunction with the approval of Ground Based Augmentation System (GBAS) Standards and Recommended Practices (SARPS) being developed by the International Civil Aviation Organization (ICAO). The Category I LAAS ground equipment specification was approved in September 1999 and associated Minimum Operating Performance Standards (MOPS) for LAAS (RTCA DO-253) were approved in February 2000. Both of these documents will allow for eventual inclusion and accommodation of Category II and III requirements as they are defined.

6.4 The FAA is pursuing an innovative approach to LAAS production, fielding, and testing and evaluation. In April 1999, the FAA established cost-sharing partnerships with two industry "Teams" lead by the Raytheon Systems Company and Honeywell to develop Category I LAAS ground equipment and avionics.

6.5 LAAS development is ongoing to result in the availability of an initial Category I public use LAAS system by mid-2002 and a Category III LAAS system by late 2005. If these operational implementations prove successful, it is the intent of the FAA to purchase up to 160 LAAS installations (Category I and III) for use in the U.S. National Airspace System (NAS). This procurement will satisfy all Category II and III precision approach requirements and supplement WAAS-based Category I precision approach service where necessary. Full LAAS deployment is planned to be complete by 2010.

7. Conclusion

7.1 GPS modernization efforts, including the decision to terminate SA, represent significant steps toward furthering the worldwide utility of GPS for peaceful civil uses. These actions demonstrate the commitment by the U.S. to providing free and improved civil GPS services for multiple applications around the globe. Continuously improving GPS services will allow for a timely transition within the aviation community from current ground-based navigation systems to 21st Century Communications, Navigation, and Surveillance Air Traffic Management (CNS/ATM) technologies and services.

7.2 However, cooperation within the international community is still essential in applying satellite technologies to aviation so that everyone fully benefits. The future success of GPS and its augmentations does not rely on the efforts of any one country, but rather on the collective efforts of many. Likewise, it is not necessary for all countries and regions to utilize the same GPS augmentation systems, but it is imperative that all countries use augmentation systems that are interoperable and support a standardized and seamless navigation system around the globe.

7.3 If you look at the history of the development of air traffic management systems and their relationship to aviation safety, you will see a compelling argument for moving forward on satellite navigation. Today's navigation equipment and procedures are so sophisticated that each technological advance only brings modest increases in overall system safety. While conventional ground-based systems will continue to play an important role in our transition to a future satellite-based operating environment, *we need satellite navigation to take aviation safety to the next level*.

7.4 The meeting is requested to note the material presented in this information paper, and consider its contribution to the implementation of a global satellite-based navigation capability to support all aviation safety-of-life operations within a regional CNS/ATM operating environment in the Asia-Pacific region. Attendees are also invited to visit the FAA's GPS Product Team's website at http://gps.faa.gov for up-to-date WAAS and LAAS program information.

7.5 For the benefit of the meeting attendees, several attachments have been included with this information paper to provide additional information on the decision to terminate SA and the performance of GPS with SA turned on and with SA set at zero. Briefly, the attachments are:

Attachment A – A copy of the White House press release on SA termination

Attachment B – A graphic showing GPS accuracy (longitude and latitude) with SA on (5/1/00) and with SA off (5/2/00)

Attachment C – A graphic showing GPS vertical error with both SA on and SA off compared to the vertical accuracy measured by the WAAS. This graphic demonstrates that even with SA set at zero, augmentation systems are needed to provide additional accuracy and more importantly, integrity.

Attachment D – A graphic showing the total GPS accuracy (longitude, latitude, altitude) over a 24 hour period for the Continental U.S. with SA off. This graphic also demonstrates that we still need augmentation systems for availability, integrity, and accuracy necessary to meet precision approach requirements (CAT-I = 7.6 meters, horizontal and vertical)